Developing a Market-Sensitive Intelligent Transportation Systems Educational Program

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Results of research undertaken to evaluate the educational needs of the emerging field of Intelligent Transportation Systems (ITSs) are presented, and whether course offerings in academic programs meet these needs is ascertained. A survey was conducted to determine needs for ITS education among public- and private-sector entities and to assess the perception of the academic sector on the type and level of ITS education to be offered. The results indicate that academic programs are aware of the educational needs of the private and public sectors in ITS and have been reacting to those needs. A traditional civil engineering curriculum is inadequate to educate engineers in ITS, thus the ITS educational program must be inter- (or cross-) disciplinary. Focus should be on the areas that are not traditionally part of civil engineering education such as communications, traffic surveillance, systems analysis, and social and institutional issues. The results are intended primarily to provide a guideline for universities to develop the content of an ITS program by identifying the type of program structure as well as the topics to be covered in the courses. A case study is presented of how such a program was implemented at the graduate level at the New Jersey Institute of Technology.

On January 10, 1996, during his keynote speech at TRB's 75th Annual Meeting, the then-Secretary of the U.S. Department of Transportation (DOT), Federico Peña, set a national goal: to build an intelligent transportation infrastructure across the United States. The secretary said that we ought to ask the same question President Eisenhower asked: How do we prepare for the next decade? Many public and private organizations and academic institutions share this concern as they are responding to these new challenges by training and hiring the workforce with skills in the development and application of Intelligent Transportation System (ITS) technology.

The purpose of this paper is to present results of research that was undertaken to evaluate the educational needs of the emerging field of ITS, and to ascertain how these needs are met by course offerings in academic programs. ITSs encompass advanced surveillance, communication, control, and computing systems, and engineering management methods and are envisioned to be able to increase safety, reduce congestion, and improve the productivity of our transportation systems.

The results are intended primarily to provide a guideline for universities to develop the content of an ITS program by identifying the type of program structure that is desired as well as the topics to be covered in the courses. They also suggest ways to do this by either redesigning the existing programs or developing a new program. A case study of how such a program was implemented at the graduate level at the New Jersey Institute of Technology (NJIT) is presented.

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BACKGROUND

Reacting to the need to assess the impact of technological changes that the development of ITS may bring to the engineering profession, NJIT applied for and received a grant from the AT&T Foundation to carry out a planning study dealing with the enhancement of the ITS content in the transportation program, which is the main educational component of the Institute for Transportation (IT). An extensive literature review and a comprehensive survey were conducted to determine the needs for ITS education and to assist the IT in modifying its curriculum to reflect the increasing role of ITS in the national economy.

The literature review surveyed papers written mostly by academics that described either the existing ITS-related academic curricula or a vision of such curricula. The results of the literature review were used in designing the survey. The survey, consisting of two questionnaires, was designed to (*a*) determine needs for ITS education among public- and private-sector entities, and (*b*) assess the perception of the academic sector on the type and level of ITS education to be offered.

The first questionnaire surveyed the needs of public- and private-sector organizations for ITS-educated employees, thus addressing their perceived demand for ITS-educated personnel. To accomplish this, the questionnaire gathered information on the ITS-related background of each company or organization. These data included information on the type and status of ITS projects, representation of various occupations within internal "ITS Groups, Teams and Task Forces," types of academic degrees of employees involved in the ITS activities, and distribution of these degrees (i.e., graduate, undergraduate, both).

The second questionnaire gathered information on the perception of the academic sector on the type and level of ITS education that should be offered. To accomplish this, information was collected on the structure of existing transportation or ITS programs in various academic programs at U.S. universities recognized for their transportation education.

The organization of this paper is as follows. First, the existing literature in the area of ITS education and training is reviewed. Second, an analysis of survey results and conclusions drawn from the analysis are presented. Third, a redesigned ITS curriculum that reflects the findings of the survey and the literature review is presented. This curriculum has been implemented within the

transportation program at NJIT, although it may be applicable and transferable to any institution with a graduate program in transportation.

LITERATURE REVIEW

The responsibility of academia in educating ITS professionals is addressed in the ITS America strategic plan (*1*). (ITS America is an umbrella organization that coordinates and fosters private/public/academic partnerships in ITS that will increase the productivity and safety of the U.S. transportation system while preserving the environment.) The document states that "[u]niversities must develop new academic programs that will educate a new type of transportation professional, one schooled in the disciplines and concepts fundamental to ITS." Research that has been undertaken to assist universities in developing such new programs is presented in several papers, some of which are referenced here.

Smith and Hoel (*2*) examine the changing role of the transportation profession and the educational needs of students who want to become transportation engineers working in ITS. The transportation engineers of the 1990s are facing new technologies such as communications, complex software, and sophisticated electronics, and must serve as technical, legal, and political experts. To educate these professionals, colleges and universities should provide them with the necessary skills in transportation fundamentals, information technology, systems engineering, and engineering management, and educate them to integrate complex systems and provide the best possible solutions to the real transportation challenges. The paper proposes a master's degree program that differs from traditional transportation curricula in that it includes courses in systems engineering and electives in electrical engineering, mechanical engineering, and computer science, and two interdisciplinary project courses.

Realizing the challenges that ITSs present to the transportation community and recognizing that continuing education and training of new engineers is essential, the California Department Transportation and the Institute of Transportation Studies at University of California at Davis conducted a study to address advanced technology opportunities and challenges. Jovanis (*3*) presents the findings of this study, which resulted in the development of a core education material that can be used as an introduction to ITS with the perspective that ITS is developed from technology building blocks such as communications, computer systems, sensors/detectors, vehicle technology, human factors, and policy issues.

Hyman (*4*) examines employment projections for ITS, assesses the implications of these projections, and sets skill requirements for technical specialists in the national labor market. The author analyzes two competing views: one that believes that there will be an adequate supply of technical personnel for ITS, and one that predicts that there will be a shortage of such personnel. He concludes that there will be an adequate supply of ITS specialists because of the shrinking size of defense contracts and the attraction of engineers and other technical specialists previously employed by the defense industry into the high-tech ITS area. Similarly, the author considers two opposing views on the educational needs of ITS. He also concludes that there is a need for substantially broader, more integrated college and university curricula to meet ITS needs. Civil engineering programs need to address the acquisition of management, organizational, cooperative, and broader technical knowledge. Engineers of other disciplines need to acquire transportation skills and knowledge, including some basic civil and traffic engineering if they want to address transportation programs effectively in ITS. The private sector is likely to provide the training for installation and maintenance of the equipment that it manufactures and to respond to essential ITS training needs that the public sector is too slow to respond to. Conclusions on these issues are also presented in a comprehensive paper by Hyman et al. (*5*). This study looks at various sources of supply, including defense conversion, the educational pipeline, and foreign-born engineers, and it examines key issues affecting supply such as growth and participation rate in the labor force.

Chen et al. (*6*) present the University of Michigan response to the needs for ITS education. They state that their ITS Certificate Program is designed to provide ITS education to both university students and practicing professionals, and to revive the interest of bright young people in transportation studies. The program has been structured as a cross-disciplinary effort and is open to anyone pursuing relevant graduate degrees.

Beaubien (*7*) recognizes that traffic engineers who had early training as civil engineers might not have the knowledge of the computer and communication technologies available in ITS; however, they have a unique understanding of traffic operations needed to ensure that new technologies address current operational problems. Because of these problems, traffic engineers should be trained and get involved in ITS since their experience is an ultimate key in the continuing success of ITS.

In an effort to develop a strategic plan for ITS education and training, ITS America convened a national invitational workshop in Reston, Virginia, in June 1995. The workshop was sponsored by the ITS America Subcommittee on Education and Training in cooperation with FHWA. Workshop groups, representing formal education (precollege through associate degrees, and baccalaureate and graduate programs), informal and nondegree education and training, public agencies, manufacturers and service providers, transportation companies, and students, addressed several demand and supply issues in the area of ITS education and training (*8*). The demand side findings identify those who need ITS education and training; they are categorized into groups such as ITS providers, decision makers, educators, students, and ITS users. It is determined that nearly all groups need in-depth information on the benefits and costs of ITS. In addition, there is a need to increase the understanding of ITS economics and the awareness of what ITS is and what it can do to improve societal mobility. Findings from the supply side suggest types of education and training programs that can fill the needs of educators and students, public agencies, private-sector companies, and ITS America. Recommendations are made for specific programs that address the needs of each of these groups.

In a paper presented during the ITS Education and Training Strategic Planning Workshop, Sussman (*9*) determines that the "new transportation professional" must have a good understanding of the issues that affect the world of transportation, the components of a transportation system, and the ways in which they fit together. A broad-based knowledge in transportation fundamentals as well as in-depth knowledge within a transportation specialty are essential to be able to address the increasingly complex transportation environment.

In summary, several conclusions can be reached. The traditional civil engineering curriculum is unable to give transportation engineers the skills required for ITS. They need to be exposed to a variety of courses from several engineering and social science

disciplines. The educational effort in ITS should thus be inter- (or cross-) disciplinary.

SURVEY RESULTS

Survey of Private- and Public-Sector Organizations

The first questionnaire was distributed through the September 1994 issue of the ITS America newsletter to individuals representing public- and private-sector companies or organizations. These companies are members of ITS America. Approximately 2,000 surveys were sent out. Sixty-three responses, or 3.15 percent of the total questionnaires, were received, 37 from the private sector, 15 from the public sector, and 11 that could not be identified as either. The ITS America list contains multiple recipients of the newsletter within a member organization (e.g., a state department of transportation or a professional consulting engineering firm), with only one member of the organization authorized to answer the kind of policy-making questions asked in the survey. Under the conservative assumption that there were, on average, two mailings per organization, the survey covered 1,000 organizations. The response rate is then doubled. Selected questions and responses to the survey are given in Table 1. A detailed list of survey participants can be found in work by Boilé et al. (*10*).

The analysis of the first questionnaire is presented in two parts. The first part, entitled "General Background Information," provides the summary on the type of projects and functional areas in which the companies in public and private sectors are engaged as well as the types of resources they either use or plan to use in their ITS activities. The second part, entitled "Perceived Demand for ITS Education," identifies the needs and desires of these sectors in receiving the ITS-related education.

General Background Information

- Among the six functional ITS areas—advanced vehicle control systems (AVCS), advanced traffic management systems (ATMS), advanced traveler information systems (ATIS), commercial vehicle operations (CVO), advanced public transportation systems (APTS), and advanced rural transportation systems (ARTS)—ATMS and ATIS are the most frequently cited areas of engagement in both private and public sectors. Seventy-six percent of the private-sector and 100 percent of the public-sector respondents are engaged in ATMS projects, whereas 62 percent of the private-sector and 80 percent of the public-sector respondents are engaged in ATIS projects.
- The overwhelming majority of the private- and public-sector organizations' projects (78 and 87 percent, respectively) are characterized as engineering.
- In both the private and public sectors, the current status of the majority of projects is research and development, or deployment (51 percent of private and 60 percent of public).
- Most of the respondents (84 percent of private and 73 percent of public) have ITS groups, meaning that several employees are working in teams exclusively on ITS projects. For the private sector, the most common size of these groups is medium (6 to 20 people) (52 percent).
- In the past 2 years, among the private organizations, 63 percent hired people with either graduate or undergraduate degrees to work on ITS projects, while 19 percent hired only people with graduate degrees, and 19 percent hired only people with undergraduate degrees, to work on ITS projects. In the public sector, 55 percent of the organizations hired candidates with either graduate or undergraduate degrees, 27 percent hired only candidates with undergraduate degrees, and 18 percent hired only candidates with graduate degrees.
- The employees within the ITS groups, were categorized as engineers, nonengineers, and technicians. Table 1 indicates that the public and private sectors appear to have different compositions of these employees.
- It should be noted that in the private sector 43 percent of all respondents have electrical and electronic engineers, followed by civil (38 percent), mechanical (24 percent), computer (19 percent), industrial (5 percent), and aeronautical (3 percent). In public sector the situation is quite different. Most engineers are civil (80 percent), followed by electrical and electronic (27 percent), mechanical (7 percent), and computer (7 percent).

Perceived Demand for ITS Education

- Universities should offer a specialization in ITS, according to 62 percent of the private-sector respondents and 87 percent of the public-sector respondents. However, 38 percent of the private-sector respondents think that this is unnecessary. This is interesting, and one can speculate that the private sector views ITS as a system integration field rather than a specific field in itself.
- There is a consensus on the type of ITS education to be offered by the universities. They should produce graduates with a broad ITS background (according to 62 percent of the private-sector and 60 percent of the public-sector respondents), specialists in certain ITS areas (21 percent of the private and 13 percent of the public), both (16 percent of the private and 27 percent of the public).
- A new hiree in the ITS area should have an undergraduate degree (according to 33 percent of the private and 47 percent of the public respondents), a graduate degree (36 percent of the private and 33 percent of the public), or either one (17 percent of the private and 13 percent of the public). In addition, 14 percent of the private and 7 percent of the public respondents stated that the level of education depends on the job.
- When it comes to job experience and qualifications, 79 percent of the private-sector and 60 percent of the public-sector respondents preferred to hire people with several years of work experience in transportation. However, only 7 percent of the private sector preferred to hire people with an ITS educational background, compared with 40 percent of the public sector. Fourteen percent of the private sector would hire either one.
- The preferred external continuing education vehicle, in both the private and public sectors, is seminars and conferences (86 and 93 percent, respectively). For the private sector, this is followed by short courses (73 percent) and professional society meetings (73 percent). In the public sector, this is followed by professional society meetings (87 percent) and short courses (47 percent). Graduate school ranked last, with 46 percent of the private and 47 percent of the public sector. The primary areas of interest for external continuing education, common to both public and private organizations, are ITS applications, systems architecture, funding opportunities, public and private partnerships, and national ITS needs. There are also some areas that are very specific and reflect the needs of each organization—for example, sensors, transaction processing, navigable data bases, and focused technical/engineering/management topics.

TABLE 1 Selected Questions and Responses of First Questionnaire

A. General Information

		Sector		
		Private [responses (%)]	Public [responses (%)]	Not-Identified [resp. (%)]
Areas of engagement[1]	AVCS	13 (35)	1 (6.7)	0 (0)
	ATMS	28 (75.7)	15 (100)	6 (54.5)
	ATIS	23 (62)	12 (80)	8 (72.7)
	CVO	14 (37.8)	9 (60)	5 (45.5)
	APTS	15 (40.5)	4 (26.7)	2 (18.2)
	ARTS	8 (21.6)	5 (33.3)	2 (18.2)
Type of ITS projects	Engineering	28 (75.7)	13 (86.7)	8 (72.7)
	Planning	17 (45.9)	8 (53.3)	4 (36.4)
	Management	16 (43.2)	6 (40)	4 (36.4)
Status of ITS projects	Research & Development	19 (51.4)	9 (60)	8 (72.7)
	Design & Testing	19 (51.4)	8 (53.3)	6 (54.5)
	Systems Architecture	13 (35.1)	4 (26.7)	1 (9)
	Deployment	19 (51.4)	9 (60)	6 (54.5)
	Maintenance	2 (5.4)	4 (26.7)	0 (0)
	Evaluation	13 (35.1)	5 (33.3)	2 (18.2)
Is there an ITS Group within your organization?	YES	31 (84)	11 (73)	10 (91)
	NO	6 (16)	4 (27)	1 (9)
ITS Group Size	Single Person	1 (3)	1 (9)	1 (10)
	Small (2-5 people)	10 (26)	7 (46)	3 (30)
	Medium (6-20 people)	19 (52)	6 (36)	5 (40)
	Large (more than 20 people)	7 (19)	1 (9)	2 (20)
Distribution of degrees within ITS Groups	only undergraduate	4 (11.5)	4 (25)	0 (0)
	only graduate	3 (7.7)	0 (0)	2 (18.2)
	both graduate & undergraduate	30 (80.8)	11 (75)	9 (81.8)
Distribution of degrees of the last two year hirees	only undergraduate	7 (18.5)	4 (27)	0 (0)
	only graduate	7 (18.5)	3 (18)	2 (18.2)
	both graduate & undergraduate	23 (63)	8 (55)	9 (81.8)
Representation of Engineers in ITS Groups	Aeronautical/Astronautical	1 (3)	0 (0)	1 (9.1)
	Civil (including Traffic)	14 (38)	12 (80)	6 (54.5)
	Electrical/Electronic	16 (43)	4 (27)	5 (45.5)
	Industrial	2 (5.4)	0 (0)	0 (0)
	Mechanical	9 (24)	1 (6.7)	4 (36.4)
	Computer	7 (19)	1 (6.7)	4 (36.4)
Representation of Non-Engineers in ITS Groups	Geologists	0 (0)	0 (0)	0 (0)
	Mathematicians	4 (10.8)	1 (6.7)	2 (18.2)
	Computer Scientists	7 (18.9)	1 (6.7)	3 (27.3)
	Economists	2 (5.4)	0 (0)	2 (18.2)
	Urban & Regional Planners	6 (16.2)	2 (13.3)	1 (9.1)
	Lawyers	3 (8.1)	1 (6.7)	1 (9.1)
	Operations Res. Analysts	2 (5.4)	0 (0)	2 (18.2)
	Management	11 (29.7)	5 (33.3)	4 (36.4)
Representation of Technicians in ITS Groups	Electrical/Electronic	11 (29.7)	4 (27)	5 (45.5)
	Engineering Science	2 (5.4)	3 (20)	1 (9.1)
	Communications	7 (19)	2 (13.3)	1 (9.1)
	Computer Programmers	6 (16)	3 (20)	2 (18.2)
	Computer Operators	3 (8.1)	0 (0)	2 (18.2)
	Mechanical	3 (8.1)	1 (6.7)	2 (18.2)
	Civil	2 (5.4)	3 (20)	0 (0)

(*continued on next page*)

- The first ranked of the internal mechanisms for continuing education in both private and public sectors is meetings and activities (86 percent and 93 percent, respectively). In the private sector, this is followed by in-house training (76 percent) and on-the-job training (68 percent). In the public sector, this is followed by on-the-job training (93 percent) and in-house training (80 percent).

Survey of Academic Programs

The second questionnaire was distributed to transportation programs at 59 academic institutions around the country. The rationale for selecting these programs was that they were members of ITS America, and as such had indicated that they have been pursuing an interest in an ITS-related educational program; the University

TABLE 1 (*Continued*)

B. Perceived Demand for ITS

		Sector		
		Private [responses (%)]	Public [responses (%)]	Not Identified [resp. (%)]
Should universities offer specialization in ITS?	YES	23 (61.8)	13 (86.7)	7 (63.6)
	NO	14 (38.2)	2 (13.3)	4 (36.4)
Should universities produce people with:	broad ITS background	23 (61.8)	9 (60)	7 (63.6)
	specialization in an ITS area	8 (21.6)	2 (13.3)	1 (9.1)
	both of the above	6 (16.2)	4 (26.7)	3 (27.3)
What level of education should a new ITS hiree have?	Undergraduate	12 (33)	7 (47)	2 (18.2)
	graduate	14 (36)	5 (33)	5 (45.4)
	either grad. or undergrad.	6 (17)	2 (13)	2 (18.2)
	Depends on the job	5 (14)	1 (7)	2 (18.2)
Do you prefer to hire people with:	ITS educational background	3 (7)	6 (40)	2 (18.2)
	work experience in transp.	29 (79)	9 (60)	7 (63.6)
	Either of the above	5 (14)	0 (0)	2 (18.2)
What are your external mechanisms of continuing education?	Short courses	27 (73)	7 (47)	7 (64)
	graduate school	17 (46)	7 (47)	3 (27)
	seminars & conferences	32 (86)	14 (93)	10 (91)
	professional soc. Meetings	27 (73)	13 (87)	10 (91)
What are your internal mechanisms of continuing education?	In-house-training	28 (76)	12 (80)	5 (45)
	on-the-job training	25 (68)	14 (93)	7 (64)
	meetings & activities	32 (86)	14 (93)	10 (91)

[1] The respondents are not engaged exclusively on the projects in one functional area. Consequently, the percentage distribution does not add up to 100%. The same is true for the answers to questions 2, 3, 8, 9 and 10 in Table 1.

Transportation Centers Program of DOT; and the Council of Urban Transportation Centers.

Twenty responses were received. Selected questions and responses are presented in Table 2. The survey results are divided into two parts. The first part, entitled "General Academic Program Information," relates the background information on the type of programs surveyed, their administrative structure, their plans for developing an ITS program, and possible constraints on implementing such programs within the existing structure of an accredited academic program, to name a few. The second part, entitled "Perceived Supply of ITS Education," reflects the attitude and efforts of academic programs in developing educational tools for serving the needs of ITS.

General Academic Program Information

The analysis reveals the following:

- Four (20 percent) of the transportation programs that responded are independent; the remaining 80 percent are administered by either the civil engineering (94 percent) or the systems engineering (6 percent) departments.
- Nine academic programs (45 percent) have an ITS program, focus, or specialization area.
- Fifteen programs (75 percent) consider the development of new courses in ITS.
- Three-quarters (75 percent) of the respondents think that the elements required for an ITS program already exist in the courses that are offered within their graduate programs.
- There is enough flexibility in course requirements in 95 percent of the institutions to allow students to follow an interdisciplinary program. This could enable students to specialize in ITS.
- All 20 institutions that responded are engaged in ITS projects. All but one have students either working on or being supported from these projects. The work on these projects involves the students working in groups in 89 percent of the institutions. There are small groups in 10 percent of the institutions, medium groups in 55 percent, and large groups in 5 percent, and it varies in 30 percent of the institutions. The background of these students varies; it is mostly civil, electrical, industrial, computer, transportation, and systems engineering, as well as operations research, computer, and information science.
- Seminars and short courses on ITS are offered by 45 percent of the institutions and will be offered by another 30 percent of the institutions in the near future. However, in 22 percent of these institutions, seminars and short courses are open only to students. The remaining 78 percent of the institutions have opened them to both students and professionals.

Perceived Supply of ITS Education

- The overwhelming majority of respondents (75 percent) believe that an introduction to ITS at the undergraduate level is essential. This introduction should be given in the departments of civil, electrical, computer, mechanical, industrial, and systems engineering, and computer, information, and social sciences. It should emphasize basic definitions and concepts and reflect the role of each department in ITS applications.
- Five (25 percent) of the respondents indicated that there should be a program/certificate in ITS at the graduate level.
- Universities should produce specialists in certain ITS areas, according to 10 percent of the respondents; people with a broad ITS background, according to 60 percent; and both, according to 30 percent of the respondents.

TABLE 2 Selected Questions and Responses of Second Questionnaire

A. General Academic Program Information

Is your transportation program:	independent	4 (20%)
	administered by a department	16 (80%)
Do you have an ITS program/focus/specialization area?	YES	9 (45%)
	NO	11 (55%)
Do you consider the development of new ITS courses?	YES	15 (75%)
	NO	5 (25%)
Do the elements required for an ITS education exist in your graduate program?	YES	15 (75%)
	NO	5 (25%)
Is there enough flexibility in course requirements for a student to follow an interdisciplinary program?	YES	19 (95%)
	NO	1 (5%)
Is your school engaged in ITS projects?	YES	20 (100%)
	NO	0 (0%)
Do you have students working or being supported from these projects?	YES	19 (95%)
	NO	1 (5%)
Are these students working in groups?	YES	18 (89%)
	NO	2 (11%)
What is the size of these groups?	small (2-3)	2 (10%)
	medium (4-5)	11 (55%)
	large (more than 5)	1 (5%)
	depends on the project	6 (30%)
Does your institute offer seminars or short courses in ITS?	YES	9 (45%)
	NO	5 (25%)
	will offer in the near future	6 (30%)
To whom are these seminars/short courses open?	Students	5 (25%)
	students and professionals	15 (75%)

B. Perceived Supply of ITS Education

Should an introduction to ITS be given at an undergraduate level?	YES	15 (75%)
	NO	5 (25%)
Should there be a program/certificate in ITS at the graduate level?	YES	5 (25%)
	NO	15 (75%)
Should universities produce people with:	specialty in certain ITS areas	2 (10%)
	broad ITS background	12 (60%)
	both the above	6 (30%)
Is a traditional civil engineering curriculum adequate to educate engineers in ITS?	YES	5 (25%)
	NO	15 (75%)

- The background of a student who wishes to get involved in ITS should be technical, from most of the engineering disciplines.
- A traditional civil engineering curriculum is deemed in adequate to educate engineers that will get involved in ITS, according to 75 percent of the respondents. The additional requirements in the program for those students who wish to pursue a focus on ITS are communications, operations research, and computer science courses, in addition to some advanced transportation courses.

CONCLUSIONS

On the basis of the literature review and surveys, the following conclusions are reached:

1. There is a consensus among the public and private sectors on one hand, and academia on the other, on the importance of ITS education. An ITS education on both graduate and undergraduate levels is essential.
2. It appears that the academic programs are aware of the educational needs of the private and public sectors in ITS and have been reacting to those needs. Academic institutions are improving their existing curricula to reflect the role of ITS by either introducing new courses or revising existing courses to include course-related ITS aspects.
3. ITS is an interdisciplinary area. The nature of the interdisciplinary aspects of ITS is reflected in the existence of ITS groups consisting of professionals from various backgrounds and educational levels. This is especially true in the private sector. A traditional civil engineering curriculum is inadequate to educate engineers in ITS, thus the ITS educational program must be inter- (or cross-)

disciplinary. The interdisciplinary element should facilitate teamwork in ITS groups of the private- and public-sector organizations that, according to the survey, consist of engineers, nonengineers, and technicians from many disciplines. These findings are consistent with the views expressed in some of the papers reviewed in the literature section (*1*,*9*).

4. Students, the future ITS experts, should be educated in areas that are not traditionally part of civil engineering education. These areas include communications, traffic surveillance, systems analysis, and social and institutional issues.

5. A dedicated degree in ITS is not considered to be essential, since, as some respondents fear, it could confine ITS education to several narrow courses. However, a core ITS program open to various disciplines such as civil, systems, electrical, computer, industrial, and mechanical engineering, and computer, information, planning, management, and social sciences, will help students from various disciplines to acquire a proper ITS education and relate their careers to ITS needs.

6. Although this may not be apparent, there may be a different opinion on how to offer the needed education to the ITS community. Although the universities believe that their graduate programs are sufficient as either a complete degree or a set of courses taken by a student in a matriculated status to meet the needs for ITS careers, 20.6 percent of the private sector believes that a narrow focus of the courses is required. This may mean that the universities may reevaluate their position not to offer a specialization in the ITS field. A set of courses under a certificate program might suit the needs especially of the private sector and be clearly more attractive. This issue needs to be clarified. It is best left to individual programs to do market research in their respective areas and determine the demand for a certificate program.

7. ITS projects are done in groups, so teamwork is essential. To prepare for teamwork, it is important that during their ITS educational experience, students from various disciplines work together in teams and become exposed to real-world ITS projects. It appears that the academic programs have recognized this need and are emphasizing the teamwork through student involvement on ITS projects.

8. There are various mechanisms for internal continuing education—including meetings and activities, on-the-job training, and in-house training—in most of the private and public organizations. In addition to the internal mechanisms, there is significant interest in external mechanisms, such as seminars, conferences, short courses, and graduate school, in most of the private and public organizations. The primary areas of interest in continuing education include systems architecture, funding opportunities, public and private partnerships, and national ITS needs. It appears that academic institutions have recognized the major role that they can play in educating ITS professionals, through short courses and seminars, and ultimately through their graduate programs.

9. The different compositions of engineering disciplines in the public and private sectors may explain the difference in their desires when it comes to hiring new employees. Forty percent of the public-sector respondents preferred to hire people with ITS education, compared with the 7 percent in the private sector. The public sector employs civil engineers (80 percent of respondents have civil engineers) and might think that they need to know more about ITS, as if it were a distinctive engineering discipline. Private-sector organizations might be more willing to train their employees. The private sector might be perceiving ITS as nothing more than a new Apollo program for the U.S. economy, and thus another large activity in the systems integration area.

RECOMMENDATIONS AND FUTURE DIRECTIONS

On the basis of the survey results, it was decided that NJIT should develop the key elements of an ITS education in its undergraduate and graduate programs. It was thought that these elements should be developed and tailored to suit the following five distinctive markets of students seeking an ITS education:

1. Individuals with superb technical and analytical skills who are interested in technology development, engineering design, hardware and software design and prototyping, systems engineering, and systems integration;
2. Individuals with solid technical backgrounds who are interested in applying well-developed (almost off-the-shelf) technologies, hardware, and software to solving particular ITS engineering and design problems;
3. Individuals with technology (and/or engineering) and management background who are interested in business venture aspects of technology, product development, marketing, costing and economic analysis, financing, and entepreneurship;
4. Individuals with solid analytical background who are interested in applications of commercially available technology, hardware, and software to solving particular problems in planning for ITS systems and services including behavioral issues related to the user acceptability of such advanced technology and services;
5. Individuals with some analytical and limited technical background who are interested in public policy issues, institutional barriers and limitations to development and applications of advanced technology in general, and ITS in particular, legal implications of ITS systems applications, and regulatory issues.

It was decided that an ITS educational program should be developed to consist of the following four components:

1. A concentration in the Interdisciplinary Graduate Program in Transportation with a set of courses emphasizing the systems and technology of ITS. The graduate program at NJIT is a free-standing academic program offering M.S. and Ph.D. degrees in transportation.
2. ITS elements in other graduate programs such as electrical and computer engineering, computer and information science, social science, and policy studies, and industrial management.
3. Undergraduate technology-oriented courses in ITS offered to engineering majors.
4. An ITS certificate program opened to graduate students already enrolled in graduate programs at NJIT and to professionals desiring to improve their ITS skills.

Program Development Stages

It was envisioned that an approach for developing the ITS educational components would be executed in four stages:

1. An urgent development of the initial ITS curriculum of interdisciplinary nature would be based on disciplines that are an integral part of ITS. Initially, this curriculum would rely on the existing courses offered across NJIT. A sample curriculum with emphasis on technology and engineering is given in Figure 1.
2. Faculty in various departments across NJIT would develop ITS elements in their courses—namely, redesign the existing courses to reflect the ITS components. For example, the redesigning

Core Courses -- 9 credits
Tran 603 Introduction to Urban Transportation Planning (CE 603)
Tran 610 Transportation Economics (IE 610)
Tran 650 Urban systems Engineering (CE 650)

Required Courses -- 9 credits
Tran 615 Traffic Studies and Capacity (CE 660)
Tran 755 Intelligent Transportation Systems
Tran 765 Multi-Modal Freight Transportation Systems Analysis (CE/EM 765)

3-6 credits from:
Tran 700 Master's Project
Tran 701 Master's Thesis

Elective Courses -- 6 - 9 credits from:
Tran 602 Geographic Information Systems (CE 602)
Tran 608 Behavioral Issues in Transportation Studies (HRM 608)
Tran 625 Public Transportation Operations and Technology (CE/IE 625)
Tran 653 Transportation Demand Management (STS 653)
Tran 752 Traffic Control (CE 752)
Tran 760 Urban Transportation Networks
EM 714 Multicriteria Decision Making
EnE 671 Environmental Impact Analysis
ME 635 Computer-Aided Design
CIS 610 Data Structures and Algorithms
CIS 651 Data Communication
CIS 661 System Simulation
EE 642 Communication Systems I
EE 609 Artificial Neural Networks
IE 624 Heuristic Methods
IE 642 Network Flows and Applications
IE 644 Application of Stochastic Modeling in Systems Control
IE 651 Industrial Simulation
IE 705 Mathematical Programming in Management Science
IE 706 A Queuing Approach to Performance Evaluation
HRM 601 Organizational Behavior
MIS 648 Decision Support Systems
MGMT 692 Business Strategy
MKTG 632 Strategic Marketing Management
MKTG 636 Product Strategy and Management
MKTG 640 Industrial Marketing Management

FIGURE 1 ITS graduate program on advanced transportation systems and technologies.

of the current EE 642 Communication Systems I would focus on current and future communications protocols for ITS.

3. A set of courses would be developed to support an ITS option in undergraduate education.

4. An ITS laboratory that will have both technology and public policy elements would be developed.

ITS in the Graduate Program

To date, within the graduate program in transportation, a concentration in advanced transportation systems and technology was developed. This concentration is designed for graduate students who were described previously as the first market. Most are already offered across NJIT, and ITS concepts have been introduced within these courses. For example, the course in Public Transportation Operations and Technology (TRAN 625) now includes the latest technological improvements in APTS such as automatic vehicle location (AVL) and automatic vehicle identification (AVI), smart-card technologies for payment of fares, and transit ATIS, to name a few. Students deal with case studies such as development of ATIS using a geographic information systems (GIS) platform, route planning algorithms, development of ride-on-demand transit services, and design of dynamic bus routes in the presence of AVL/AVI systems. Similarly, the Transportation Economics (TRAN 610) course considers the economic impacts of ITS. It involves case studies with cost-benefit analyses of alternative systems and technologies (e.g., different traffic surveillance and communication technologies). Transportation Finance (TRAN 643) deals with case studies on public/ private partnership for financing new intelligent transportation systems and toll roads.

Within GIS (TRAN 602), students are expected to participate in a development of a generic ATIS system using the ARC/INFO software. They are asked to enhance the Multimodal Advanced Traveler Information System, which was developed at IT. The enhancements include the interface of traffic simulation software such as TRAF-NETSIM and representation of traffic conditions on the links of the network in different colors; and representation of different types of roadway services using special symbols, such as gas stations, hospitals, restaurants, and other yellow-page type of information. In traffic management applications, the students are asked

to design different functions to the GIS, such as identifying faulty detectors or traffic controllers and displaying them using special symbols, display incidents, communication links of the facility, truck routes, roadway signs, and variable message signs, and developing a function to monitor the position in real time of different emergency services.

In addition, a new course—TRAN 755 Intelligent Transportation Systems—dedicated exclusively to new systems, technology, and operations has been introduced. It deals with case studies on developing real-time route planning algorithms; evaluating different real-time route planning algorithms; developing regional multimodal traveler information systems, decision support systems for regional incident management, incident detection algorithms for freeway facilities and urban signalized networks, and travel time estimation and prediction algorithms; and evaluating different traffic surveillance and communication technologies as well as the use of centralized communication systems versus distributed communication systems.

Students with the educational desires and background specified in the second market area are encouraged to take the Transportation Engineering area of study. Students in Civil Engineering and Industrial and Manufacturing Engineering are also encouraged to take the ITS-related transportation courses. Students with the needs described in Areas 3–5 are recommended to take courses in Industrial Management and Social Studies and Policy Studies.

Undergraduate Course

On the undergraduate level, NJIT is developing an analytical course that will serve as an introduction to the ITS transportation area. To secure the approval of the undergraduate advisors in the departments of Electrical and Computer Engineering, and Computer and Information Science, the course had to be of a technical nature and challenge the students' analytical skills. This course will offer students an opportunity to learn about the necessary systems approaches, procedures, tools, algorithms, and technologies required for the planning, design, and operation of ITS. This will prepare them for studies at the graduate level, or concentrate their studies to specific fields at the undergraduate level. The students will be required to design computer programs for the algorithms to be presented in class, develop statistical models for travel time estimation and prediction, understand the traffic flow models presented in class, and be able to make inferences on the models developed. The course provides an opportunity for students from different disciplines (civil, electrical, computer, and industrial engineering, computer science, industrial management) to work in groups on real-world ITS applications (e.g, work on TRANSMIT project, an evaluation of the ETTM-based incident detection algorithm). The proposed course outline is given in Figure 2, which shows the course's emphasis on case studies each dealing with an important ITS application.

1. Introduction to Intelligent Transportation Systems: Principal Components of the Transportation System; ITS in the US, Europe and Japan.
2. An ITS Planning Process
3. ITS System Architecture
4. Overview of traffic flow theory.
5. Route Planning Algorithms: Static; Time Dependent. CASE STUDY 1
6. Incident Detection Algorithms. CASE STUDY 2
7. Hypothesis Testing: Statistical Distributions; Hypothesis Testing of the mean and variance.
8. Regression Analysis: Ordinary Least Squares, Multiple regression analysis.
9. Travel Time Estimation and Prediction Models. CASE STUDY 3
10. Traffic Assignment: Static; Dynamic.
11. Mid-term.
12. Introduction to communications.
13. Communications in ITS: Infrastructure to Infrastructure; Infrastructure to vehicle; Vehicle to Vehicle.
14. Traffic Surveillance: Loop detectors, Optical Detectors, Microwave Detectors, Acoustic Detectors, Video Image Processing, Closed Circuit TV.
15. FINAL. Student Presentations on Case Studies; Submit case study Report.

Textbook

1. "Urban Operations Research", Larson and Odoni, Prentice Hall, 1981.
2. "Introduction to Operations Research", Hillier and Lieberman, McGraw Hill, 1990.

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4. ITS America Proceedings, 1993 -- 1996.
5. Transportation Research Record papers on ITS.
9. IEEE papers on ITS.
10. Other Journal Publications on ITS.

FIGURE 2 Course outline for ITS course "Analytical Techniques in ITS (TRAN 555)."

1. **Data Processing in ITS**
   - TRAN 555: Analytical Techniques for ITS
   - TRAN/CE 615: Traffic Studies and Capacity
   - TRAN/CE 752: Traffic Control
   - CIS 610: Data Structures and Algorithms
   - MATH 669: Statistics for Engineers

2. **Travel Demand**
   - TRAN/CE 602: Introduction to Urban Transportation Planning
   - TRAN/STS 670: Transportation Demand Management
   - TRAN/STS 720: Discrete Choice Modeling for Travel Demand Forecasting
   - TRAN/HRM 608: Behavioral Issues in Transportation Studies

3. **Telecommunications**
   - CIS 651: Data Communication
   - EE 642: Communication Systems I
   - TRAN/CE 752: Traffic Control

4. **Multi-modal Transportation**
   - TRAN/CE 602: Introduction to Urban Transportation Planning
   - TRAN/CE 765: Multi-modal Freight Transportation Systems Analysis
   - TRAN/CE/EM 740: Management of Transportation Carriers
   - TRAN/CE 654: Mass Transportation Systems

5. **Advanced Transportation Management Systems**
   - EE 642: Communication Systems I
   - CIS 610: Data Structures and Algorithms
   - TRAN/CE 752: Traffic Control
   - CE 611: Project Planning and Control

FIGURE 3 Sample certificate program with TRAN 755 as core.

Certificate Degree Program in ITS

The certificate program is in the planning stage. A sample program is shown in Figure 3. The program uses existing courses that will be enhanced with ITS technological developments and case studies. The program may be offered to full-time, part-time, or nonmatriculate students. The students who wish to enroll in the certificate program will have the option to continue to complete a master's degree in transportation or in another discipline if they fulfill degree requirements of each individual department. The certificate program will require the completion of 15 credit hours and a paper on an ITS topic or case study.

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